SNS 109000000-SR0001-R00

Spallation Neutron Source

Systems Requirements Document for WBS 1.9 Integrated Controls Systems

January 2000

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A U.S. Department of Energy Multilaboratory Project

SPALLATION NEUTRON SOURCE

Argonne National Laboratory • Brookhaven National Laboratory • Lawrence Berkeley National Laboratory • Los Alamos National Laboratory • Oak Ridge National Laboratory

SNS

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FOR WBS 1.9 INTEGRATED CONTROLS SYSTEMS

January 2000

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1. SCOPE

1.1 DEFINITION OF WORK

The cost estimate and schedule for providing the scope of work defined in this document are included in the project Cost Estimate Database (CEDB) Revision 3, dated July 1999 and the Integrated Project Schedule (IPS) Revision 0, dated July 1999. Detailed descriptions of the scope of work for level 2, 3, and 4 WBS elements is included in the WBS Descriptor Forms document SNS 100000000-BL-002 dated July 1999. The scope includes this July 1999 baseline and the following approved PCRs which impact WBS 1.9:

PCR Number	Description	Status
PCR PS 00 001	CEDB Corrections	CEDB Rev 2
PCR CO 00 001	Cabling Coordination	CEDB Rev 17
PCR CO 00 002	Personnel Protection Cabling	CEDB Rev 18

WBS 1.9 will implement a single, integrated, plant-wide control system that will provide control, monitoring, and data acquisition services for SNS, a Personnel Protection System (PPS) that provides personnel access controls in areas with radiological hazards, and standards for controls-related items that should be similar in all systems.

As shown in Table 1; WBS 1.9, Integrated Controls Systems is divided into four parts - (1) Global Controls, (2) Distributed Controls, (3) Selected Project-wide Standards, and (4) Personnel Protection System. Parts (1) and (2) form the plant-wide integrated controls system. It is referred to as the "Integrated Control System," or "ICS" and consists of global controls that provides common services across the facility and distributed controls that provides local Input/Output (I/O) and software specific to technical and conventional facilities systems.

All R&D, design, software development, Title III support, procurement and fabrication of installed equipment, installation, and system testing without beam will be provided.

Spares needed to support system testing, commissioning, or operations are not included in the WBS 1.9 scope.

Title III support will include technical support for procurement and fabrication, as-built drawings, software documentation, test procedures, training materials, and operating procedures. It is assumed that operations staff (WBS 1.10) will complete the training materials and operating procedures and thus the cost of this effort is not included under WBS 1.9.

WBS 1.9 funded activities for distributed controls systems (WBS 1.9.3 – 1.9.8 and 1.9.10) end with readiness review approval for commissioning of technical systems and turnover to operations of conventional facilitiesand Central Helium Liquefier (CHL) controls. Technical support for operating these systems during commissioning is not in the WBS 1.9 scope of work.

Since WBS 1.9 global controls and PPS systems (WBS 1.9.2 and 1.9.9) support every technical system, global controls and PPS systems will be logically divided into subsystems and turned over to operations by subsystem. WBS 1.9 funding will end when all of the hardware and software in these systems has been tested and turned over. This expected to be completedapproximately 10 months before the end of the project. Support for operations beyond the acceptance test is not included in the WBS 1.9 scope of work.

The project will generate a project-wide database that will include data needed for beam physics calculations, EPICS software development, and equipment, cabling and other design data. WBS 1.9 will fund and bear responsibility for developing requirements, configuration and data input for the EPICS configuration database and design data for controls equipment and cabling. WBS 1.9 will fund 0.5 FTE toward administration of the database. Database development for support of physics beam calculations and mechanical systems and components is not included.

WBS 1.9.9 does not include locking devices for breakers, a large lockout/tagout (LOTO) panel in the control room or other LOTO equipment for power system equipment.

It has been proposed that some accelerator analog signals be hardwired to the control room for viewing by a oscilloscope type system. Provisions for these hardwired signals and the system to read them are not included in the present cost estimate.

Table 1-1. Integrated Controls Systems Major Elements

Major Part	WBS No.	WBS Name	Key Elements
	1.1.9	R&D	Standards, driver development, hardware testing, global systems requirements and software development stations at each laboratory
	1.9.1	Management & Integration	Management and integration activities, technical systems cabling management, and a controls laboratory and software development station at ORNL
Global Controls	1.9.2	Global Systems	Main and local control room equipment, Integrated Control System (ICS) network, timing system, Equipment Protection System (EPS), EPICS configuration database and global applications and system programming
Distributed Controls	1.9.3	Front End Systems Controls	Input/Output Controller (IOC) hardware and IOC-resident software and engineering screens specific to Front End systems.
Distributed Controls	1.9.4	Linac Systems Controls	Input/Output Controller (IOC) hardware and IOC-resident software and engineering screens specific to Linac systems.
Distributed Controls	1.9.5	Ring Systems Controls	Input/Output Controller (IOC) hardware and IOC-resident software and engineering screens specific to Ring and Transfer Line systems.
Distributed Controls	1.9.6	Target Systems Controls	Input/Output Controller (IOC), PLC hardware and software specific to Target systems, and IOC-resident software and engineering screens specific to Ring and Transfer Line systems.
Distributed Controls	1.9.7	Instrument Systems Controls	Input/Output Controller (IOC) chassis specific to Instrument systems.
Distributed Controls	1.9.8	Conventional Facilities Systems Controls	Input/Output Controller (IOC) hardware and IOC-resident software and engineering screens specific to Conventional Facilities systems.
Distributed Controls	1.9.10	Cryogenics Plant Controls	Input/Output Controller (IOC) and PLC hardware and software and engineering screens specific to cryogenic plant systems.
Standards	1.9.1	Management & Integration	Cabling requirements Equipment, device, and signal naming requirements Cabinet/rack design standards PLC design standards Controls network equipment standards
PPS	1.9.9	Personnel Protection System	All Personnel Protection System equipment (including cabling) and software. IOC interface for integration of PPS.

1.2 INTERFACE DEFINITION

Figure 1.1 shows the interfaces between WBS 1.9 and other project WBS elements. It also shows cabling and raceway interfaces.

Figure 1.2 shows generic Input/Output Controller (IOC), Programmable Logic Controller (PLC) and equipment interfaces. Except where noted explicitly, the interface to the ICS is at the front panel of a crate-based I/O system, such as PC, VME or VXI, or at a transition module where cable break-out and/or signal conditioning takes place. In some cases, where in-house designed VXI modules are used (examples include low-level RF instrumentation and beam diagnostics instrumentation) the interface may be at the crate back plane. Industrial I/O modules may be packaged in an industrial chassis (e.g. PLC) and scanned from a VME crate. By negotiation, the PLC may be a part of the ICS, or of the system with which it was supplied.

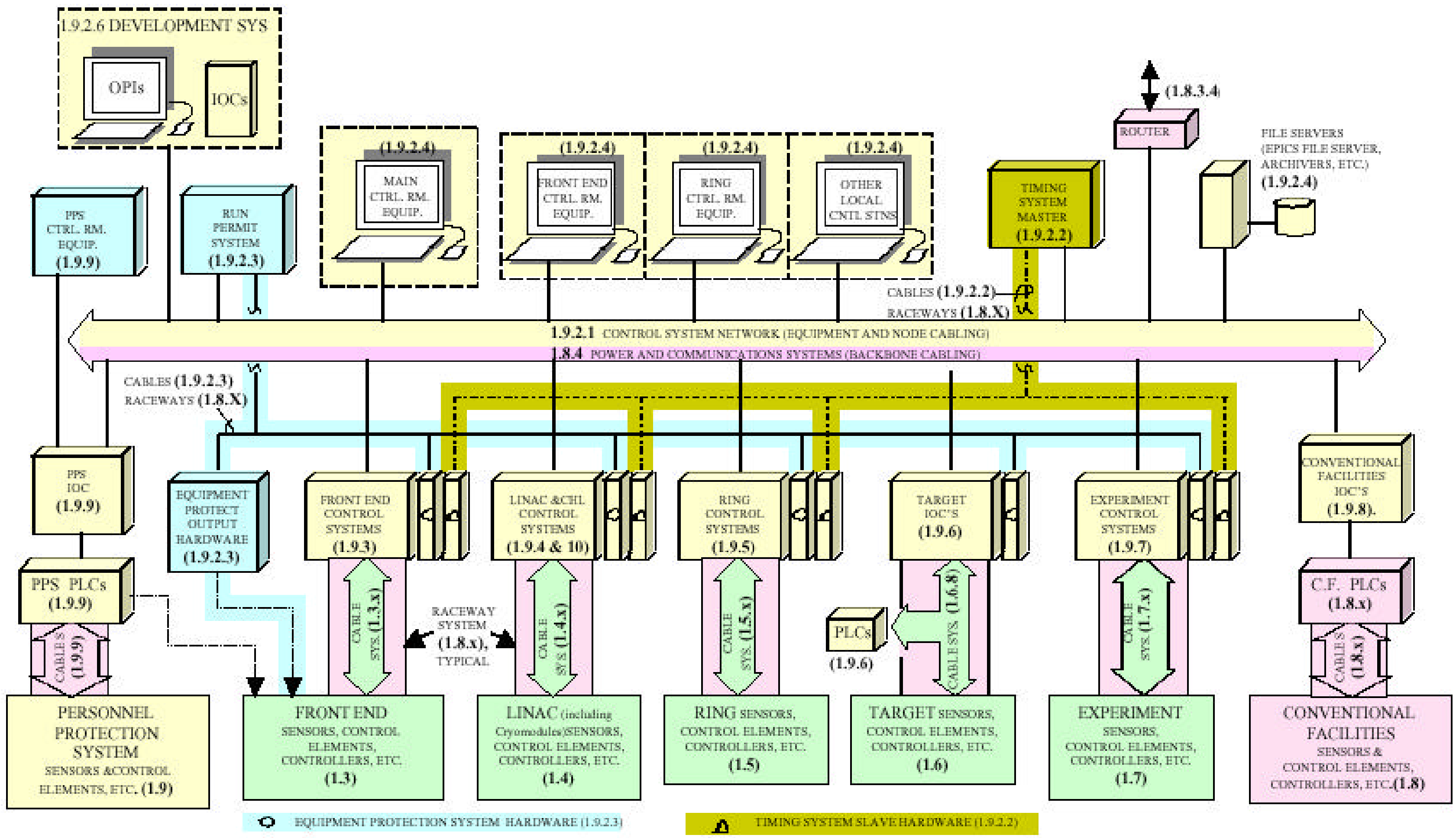

Fig. 1-1 Integrated Control System (ICS) System Diagram

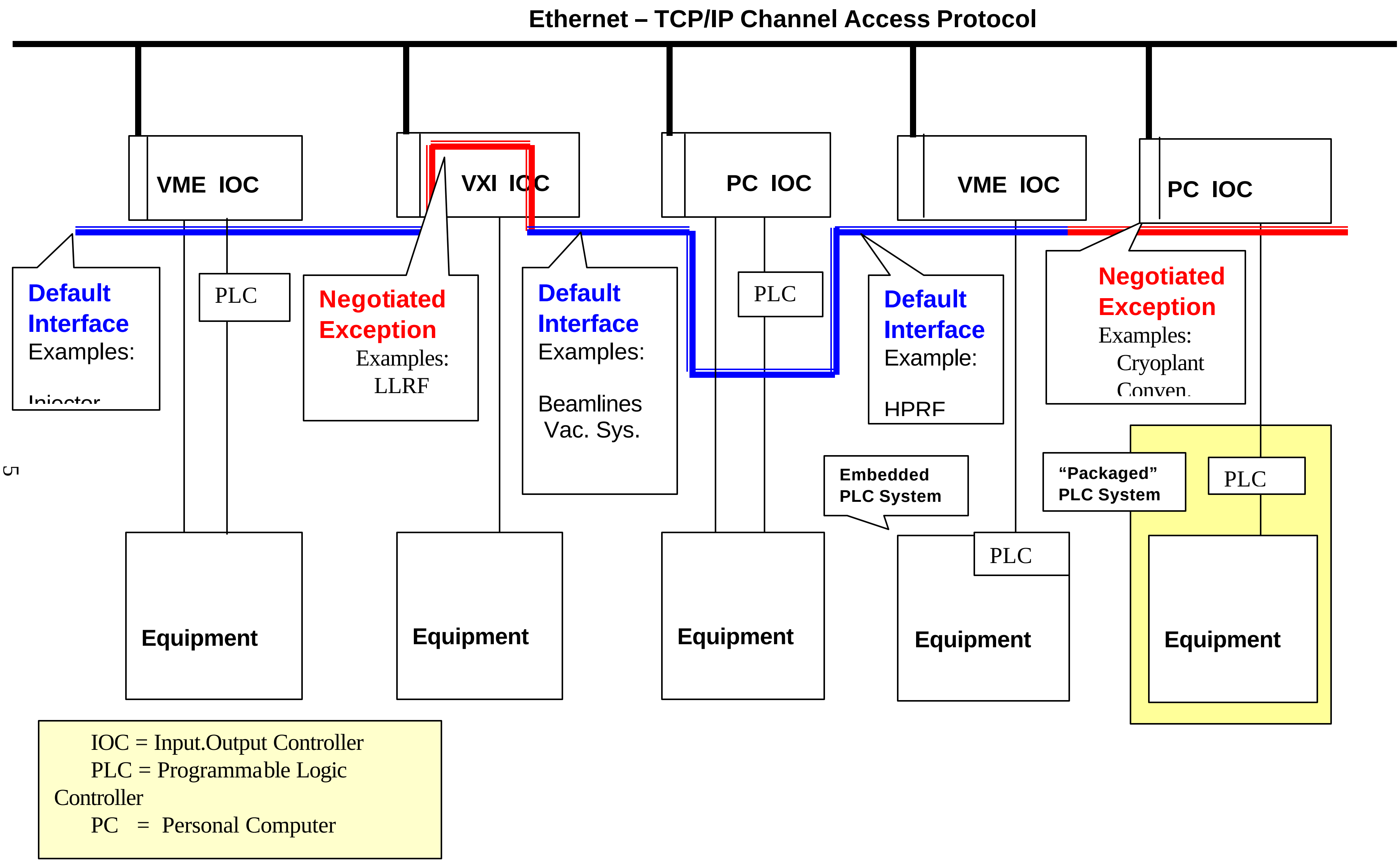

Fig. 1-2. Interface Diagram.

2. INTEGRATED CONTROL SYSTEM (WBS 1.9.2)

2.1 ICS FUNCTIONAL REQUIREMENTS

ICS provides the following functionality:

- Operator Monitor and Control
- Data Acquisition for Accelerator Physics
- Save and Restore
- Alarm Management
- Archiving and Retrieval
- Automatic Sequencing
- Closed-Loop Control
- Mode Control
- Modeling and Simulation

2.2 USER REQUIREMENTS

The ICS is required to serve the different classes of user described below:

- **Equipment Design Engineers—**During construction and testing of individual subsystems, design engineers require a stand-alone system that can be located close to the equipment and possibly moved with the equipment from factory floor to its final installation location. To ensure that testing is complete and is relevant to the final system, the control system interface should be the same as planned for operation, both at the hardware and at the operator level. Equipment design engineers require that the control system provide access to all available diagnostic information to assist with commissioning and debugging of the equipment. Equipment should be built with self-diagnostics, and these should be available to the control system to assist with equipment maintenance.
- **Control System Engineers—**The control system must provide to its own engineers, both on request and in an archive, data on its own status and behavior. This should include such information as CPU loading, network loading, processor and process heartbeats, connectivity status, and reports of any control system faults or errors. This information is required during all phases of operation but is most important during commissioning and routine operation.
- **Accelerator Physicists—**Maximum demands are made on the control system by accelerator physicists during the commissioning phase. This phase is when the functional requirements listed below under "Data Acquisition" and "Modeling and Simulation" are most heavily used. The control system must be designed for the bandwidth and processor demands anticipated during this time. In addition, the control system must facilitate the rapid implementation of newly conceived diagnostic programs and the interfacing of acquired data with a variety of analysis programs. Application program interfaces must be carefully designed to meet this requirement.
- **Operators—**The primary users of the control system are the accelerator operators. Where there are conflicting requirements, these should be resolved in favor of ease and safety of routine operation by the operations team. The control system should provide data as predictably, unambiguously, and efficiently as possible. This requirement implies, among other things, a clear, consistent, plantwide naming convention. The system should include an on-line help facility to expedite access to manuals and other documentation when required. Procedures should be automated wherever possible to reduce routine tasks. The system should encourage and facilitate the keeping and passing of operation logs, particularly from shift to shift. Alarm and error messages must be clear and unambiguous (no "Error # 3476221"), and action should be recommended.

- **Experimenters—**Experimenters making use of neutron beams also require information from the control system. Here the emphasis is on accelerator and target status and performance, as well as on control of each beamline. In addition to information on the status of the machine, some experiments may require timing signals. In addition, the control room may require some data available from experimenters, such as target performance, so two-way communication is required. It is common practice in light sources and other neutron facilities to allow remote access to their experiments and beamlines to off-site experimenters. The Experimental Physics and Industrial Control System (EPICS) system proposed for use by SNS already incorporates a "gateway" capability, allowing safe remote access (with limited performance) for just such applications.
- **Maintenance Engineers—**The control system must provide useful fault diagnoses to assist with equipment maintenance. It should provide an easy interface to databases of equipment properties, manufacturers, documentation, locations, cabling data, and fault histories. It should also provide access to fault prediction algorithms to allow for scheduled maintenance of components likely to fail.
- **Facility Managers and Overseers—**The control system should be capable of producing operating reports and statistics in a form required by facility managers, site overseers, and regulating agencies.

2.2.1 Performance Requirements

Performance requirements are given in Table 2-1.

Table 2-1. Control system performance parameters

Parameter	Value
Total facility I/O channel count[1]	38,700
Front end number of I/O channels [1]	2,200
Linac number of I/O channels [1]	21,500
Ring and transfer line I/O channels [1]	9,000 (Many are wave forms)
Target I/O channels [1]	1,700
Conventional facilities I/O channels [1]	4,300
Console update rate	>5 Hz/displayed channel or 1000 displayed channels/sec
Time to bring up new screen	<1 sec
Time for fast protect to turn off beam	<10us
Maximum use of IOC capacity	50%
Maximum IOC to IOC response	0.1 sec
Time stamp resolution (EPICS)[2]	(<16ms)
Trigger system resolution	(1us – or one turn)
Total archive rate[3]	10,000 pts/sec
Total archive capacity	0.5 gigabyte/day
Total network bandwidth[4]	17 Mbits/sec (minimum)
Availability (ICS total)	>99%

Note: IOC = input-output controller.

[1]Channels: In general, a "channel" is a single signal or named measurement or setpoint. Note however that some channels are complex, and in the beam instrumentation case, one channel may represent a complete waveform. The number of channels has been rounded up to reflect the uncertainty of these estimates. Channel counts for front end, linac, ring, targets, and conventional facilities reflect data given in the corresponding design manual sections. Channel estimates at the conceptual stage of similar projects have frequently been low. Larger numbers are assumed where appropriate for conservative design.

[2]Time stamp resolution. The time associated by EPICS with acquired data will allow events associated with a given macropulse to be correlated.

[3]Archiving rate. Based on a maximum archive rate of 1000 pts at 10 Hz. A background rate of all channels (50,000) every 5 minutes is negligible.

[4]Bandwidth. Display: 40 screens @ 100 pts/console @ 10 Hz @ 24 bytes/pt. @ 10bits/byte = 9.6 Mbits/sec Archive: 10K pts/sec @ 24bytes/pt @ 10bits/byte = 2.4 Mbits/sec Total = 9.6Mbits/sec (Display) + 2.4 Mbits/sec (Archive) + 5Mbits/sec (Misc) = 17 Mbits/sec

2.3 GLOBAL SYSTEMS (1.9.2)

2.3.1 Control System Network (WBS 1.9.2.1)

The control system communication network carries all computer communication related to the functions of the SNS Integrated Control System. This includes the real-time control messages for active running of the plant; general file transfers needed for control system software development, and any needed connections of the control system to external networks (ftp, www). General-purpose communication, related for example to business computing or experimental data analysis is not in the scope of the control system network.

The control system must connect to the following component types:

- IOCs and Consoles associated with EPICS (generally comprising WBS 1.9.3–9);
- File servers holding setpoint configurations and archival data associated with running the accelerator and analyzing or modeling its performance (also WBS 1.9.3–6);
- Other dedicated computers supplying external needs such as WWW access or gateways to external networks.

2.3.2 Timing System (WBS 1.9.2.2)

The timing and synchronization system is independent of (but interfaced to) the supervisory (EPICS) control system. This system includes master (centralized) and slave (distributed) timing modules and an "event" distribution system, as well as all necessary synchronization electronics.

The Timing and Synchronization system has two primary functions:

- To allow precise time stamping of acquired data for on-line or subsequent event correlation and reconstruction.
- To provide for the overall synchronization of facility subsystems, including (starting at the low-energy end) the front end proton chopper/buncher system, the linac rf systems, the transport line debuncher, ring injection, the ring rf system, the ring extraction system, and the post-target neutron chopper systems in each experimental neutron line. Throughout the facility, beam instrumentation must also be synchronized with the time structure of the beam.

Detailed requirements for the timing system are contained in the Systems Requirements Document for the SNS Timing System, SNS 109020000-SR0001.

WBS 1.9.2.2 Includes a master timing event generator, software to program this device, distributed "slave" modules and a distribution system.

2.3.3 Equipment Protection System (EPS) (WBS 1.9.2.3)

Three functions will be provided to protect equipment:

- a "run permit" function;
- a beam pulse permit function;
- and a fast protect function.

Note: The present WBS 1.9 cost estimate does not support both the beam pulse permit and a fast protect system.

"Run permit" and "beam pulse permit" verify the operational status of a specified list of equipment and interlocks before allowing beam to be enabled. They are sensitive to the operating mode of the facility, as the permit chain is dependent upon that mode. (See "mode control," below.) Complementing these permit functions, a "fast protect" system will shut off the beam in a matter of microseconds if an anomalous condition—radiation level or equipment failure—is detected. The fast protect system will serve as an essential tuning aid and will be designed to allow quick restoration of the beam once the anomalous condition is corrected.

Detailed requirements for the Equipment Protection System (EPS) are contained in the Systems Requirements Document for the SNS Equipment Protection System, SNS 109020000-SR0001.

WBS 1.9.2.3 does not include the actual hardware which inhibits and/or turns off the beam, but does include the electronics to activate this hardware, as well as distributed protection modules, a distribution system and software to program the system. Conditioned inputs to this system are NOT included in this WBS element.

2.3.4 Control Rooms

The control room WBS includes all ICS and PPS the equipment – consoles, computers and peripheral devices that are located in the SNS Main Control Room and local control areas.

The Main Control Room (MCR) must provide a central location for all SNS operational activities. There must be adequate console space to accommodate commissioning and routine operations of all aspects of the SNS facility. In addition, the capability must be provided for local operations during maintenance and equipment commissioning.

It has been proposed that some accelerator analog signals be hardwired to the control room for viewing by a oscilloscope type system. Provisions for these hardwired signals and the system to read them are not included in the present cost estimate.

Except for the hardwired signals described above, all operator interface with signals entering the Main Control Room will be via the EPICS system.

2.3.5 Software Development System

The software development system covers the evolving hardware (computers) and software needed to support software design during design, construction, and operation of SNS. Although some hardware required for operation and construction, such as networking equipment, file servers, and so forth, will be utilized to some extent, this item refers to additional components.

Control hardware will not be available during the initial design and construction phases of SNS. Thus, it will be necessary to have separate and independent systems dedicated to software development at each participating lab. Licenses will be required for some commercial software, such as compilers, operating systems, analysis/design tools, and code management/release tools. The latter has the additional requirement of allowing concurrent, multi-site, shared ("remote") development until the development and maintenance activity is consolidated at the SNS site.

Software development systems will include the ability to *simulate* accelerator, target, and conventional facility processes.

2.3.6 Software (System and Application) Requirements

Global application programs will use EPICS and provide the following:

- **Operator Monitor and Control**—The SNS control system will provide the capability for facility operators to monitor and control the status of the facility in a safe and efficient manner. This capability will be available both from a common, central location—the main control room—and, in some circumstances, from locations closer to the subsystems and equipment (local control). In general it will be possible to monitor *all* facility parameters, but to control only those permitted by the people responsible for the subsystems. Tools will be available to present data in ways that maximize information transfer to the operators (e.g., color, graphics).

- **Data Acquisition for Accelerator Physics**—The SNS control system will provide a flexible means of acquiring data for analyzing beam behavior to aid understanding of the physics of the accelerator. From provided beam instrumentation, it will be possible to acquire measures of transmission and transverse and longitudinal beam motion, and to correlate these data with each other or with any other machine parameter. It will be possible to acquire these data both synchronously and asynchronously. Tools will be provided for both analysis and visualization of these data and for passing acquired data to off-line programs. A mechanism will be provided to initiate this data acquisition upon operator request and under program control.
- **Save and Restore**—Both for operational efficiency and for subsequent performance analysis, the SNS control system will provide a facility that saves the operational status of the accelerator and targets and then restores that status on request. As a minimum, this facility will save all relevant (to restoring the beam) set points, although a more sophisticated tool that saves beam properties and tunes the beam to reproduce them may be required. This facility will allow the saving of more than one beam tune and the selection, from a number of possibilities, of the tune to be restored. It will also allow a return to conditions at some marked moment in order to reverse unsuccessful tuning.
- **Alarm Management**—The SNS control system will provide a sophisticated alarm management system. This system will allow the reporting of various event, alarm, trip, and error conditions, using a severity encoding scheme to ensure appropriate operator response. The alarm system will allow the reporting of alarms hierarchically, to limit the data reported in the (not uncommon) situation of cascading alarms. A method will be provided to determine the root cause of an alarm cascade, and all alarms will be time-stamped to a precision allowing for subsequent event analysis. The system will include a report-generating capability to assist with understanding and analyzing the reliability, availability and maintainability (RAM) performance of the facility. Where possible, the alarm management system will be capable of advising the operator of the appropriate response or of triggering an automated response.
- **Archiving and Retrieval**—The SNS control system will provide a flexible data archiving and retrieval system. This system will be capable of gathering and storing data either at regular timed intervals, or upon request, or at specified events—possibly simply synchronization events. Data acquisition rates will be variable and operator programmable, with different rates for different parameters as appropriate. The system will be capable of storing large amounts of data for long periods of time. Since the archive is of little use without a sophisticated retrieval system, this system will allow retrieval of archived operational data in time to be useful and will be able to present the retrieved data in several different ways. It will be possible to present retrieved data in formats compatible with on-line visualization and data analysis tools. This archiver is limited to data gathered by the controls system and related to the state and performance of the accelerator, storage ring, and targets. Experimental data are stored by separate experimental data acquisition systems.
- **Automatic Sequencing**—For increased operational efficiency, and in support of a demanding accelerator availability requirement, the control system will include the capability of automatic sequencing, including decision-making. These sequences could include automatic run-up procedures, automatic fault-recovery sequences, and automatic data-taking routines.However, they will not include automatic tuning of the accelerator. The system will provide simple tools for defining sequences as experience is gained and will be capable of monitoring the status of automatic sequences, annunciating problems encountered in sequences, and intervening or overriding sequences if necessary.

- **Closed-Loop Control**—Autonomous, closed-loop control will be provided for SNS processes. Examples of systems that may require closed loop control include the ion source, various cooling loops, and beam control in the ring and transfer lines. It will be possible to turn these closed loops on and off and to adjust their control parameters.
- **Mode Control**—SNS will have a number of distinctly different operating modes (e.g. source tuning, linac tuning, ring tuning, neutron production, single pulse, low duty cycle, low current, etc.), each with its own set of configuration requirements and permissive conditions. The SNS control system will allow operators to select the desired operating mode, will aid in setting up for operating in this mode, and will automatically apply the proper set of operating permissives for this mode.
- **Modeling and Simulation**—Accelerators are designed using models. The SNS control system will include the capability for operators to connect with a simulator based on these same accelerator models. The simulator can then be used for exploring "what if" scenarios. The model can also be used to aid understanding of unexpected beam behavior and to suggest corrections. Finally, if required by the operations plan, this simulator could be used to assist with operator training. This modeling and simulation effort is included in the WBS 1.10 scope – not WBS 1.9.

2.3.7 Databases

In addition to these applications, the following project databases will be provided:

- **Device Database**—Sometimes known as the configuration database, this database contains all the information related to the devices and their controllers that are connected to the control system. It includes the location (in control system hardware) of control modules, scanning rates, warning and alarm limits, engineering unit conversions, etc. This database should be changed as changes to the control system configuration are made, and it should be possible to derive the on-line distributed EPICS database automatically from this off-line database. Although there is no such requirement, this database is well-suited to the use of modern object database technology.
- **Machine Models**—Descriptions of the accelerator used by machine models are contained in databases used during the design phase and need to be accessible to the control system for on-line or off-line modeling. This includes the accelerator lattice database, and a magnet database with magnet mapping data.
- **Tunes and Archives**—The existence of an archiver implies the existence of a database to facilitate accessing of archived data. Those data include machine parameters and beam characteristics as a function of time and of each other. The database must be capable of presenting archived data to control system applications so that the same tools and programs can be used on archived data as on live data. This database is very large, and sophisticated database management tools and retrieval strategies are required to make it useful. The actual size of the on-line retrievable database depends upon operational policy decisions on the amount and frequency of routine data-taking.
- **Operations Log**—The operations log will be maintained electronically, and the database of log entries must be accessible on-line by date, shift name, operating conditions, and keywords.
- **Reliability Statistics**—Related to the operations log will be a database of reliability statistics (e.g., trips, errors, beam interruptions, equipment failures) used for analysis of RAM performance of the facility.
- **Cable Database**—To facilitate maintenance of the control system and other components, a cable database will be maintained. It will contain the physical characteristics, numbers, colors, and routings

of all the cables in the installed plant. It needs to be created and used at the time of cable installation and then available on-line to operators to assist with maintenance and trouble shooting. Many commercial databases are available with this function; their interfaces should be carefully considered for ease of operational integration.

3. FRONT END CONTROL SYSTEMS (WBS 1.9.3)

3.1 CONTROLS INTEGRATION

3.1.1 Scope

Front End controls integrates the control and monitoring functionality of the Ion Source/LEBT (1.9.3.2), the RFQ (1.9.3.4), the MEBT (1.9.3.5)), and Vacuum/Cooling (1.9.3.6) hardware. The scope of Frond End controls is bounded on the hardware side by the cables leading to/from actuators and sensors, or to/from embedded equipment such as PLCs supplied by vendors; and by connection to the global timing and beam-permit signals. Special diagnostic hardware is outside the scope of Front End controls but a suitable hardware/software interface to such equipment will be provided. On the software side, Frond End communicates with the Global system and other technical systems (Linac, Ring, Target).

3.1.2 Requirements

Front End controls must provide high-level console and data-server functionality consisting of an operator interface ("look and adjust", alarm notification), data archiving, and saving and restoring of setpoints, using configuration tools, and it must provide suitable tools to allow Front End specialists to implement modeling, startup and shutdown sequencing, and feedback using both configuration tools and programming methodologies.

Front End controls must supply low-level functionality consisting of real-time control processes capable of acquiring timely data from all sensors with smoothing, scaling, and alarm generation; sending timely data to all actuators based on open- or closed-loop control, with appropriate limits for range and rate of change; and provide local, fast feedback loops; and maintain sychronism with the global timing system. In some cases, external, embedded controllers will require interchange of data based on computer protocols rather than on electrical signals.

Front End operations will normally be conducted from the main control room. However, a local console will be provided for operating all components (Ion Source, LEBT, RFQ, MEBT) during maintenance periods. An additional control station will be provided to support continuous and concurrent operation of a local ion source test stand located in the front end building. Because this operation must be independent of the primary ion source, duplicate IOCs and associated cabling and electronics will be provided.

Table 3-1. FE System Channel Estimates

	AI	AO	DI	DO	Total Channels
Source/LEBT	52	25	68	38	183
RFQ	208	16	16	0	240
MEBT	111	39	127	71	348
Vacuum and Cooling	52	6	139	132	329
Total Channels	423	86	350	241	1100

4. LINAC CONTROL SYSTEMS (1.9.4)

This WBS provides hardware and software to integrate signals from Linac vacuum, cooling water, diagnostics, and Rf power systems. The interface between the ICS and these systems (WBS 1.4) is at the IOC (See Figure1.2). WBS 1.4 is responsible for field equipment, signal cabling, non-VME hardware and its associated software. WBS 1.9.4 is responsible for IOC hardware, IOC software, development of subsystem-specific client applications, and related operator displays.

4.1 VACUUM AND COOLING SYSTEMS

There are two distinct types of cooling system: those which are used simply to prevent the overheating of equipment and whose function is interlocking and equipment protection; and those which are used to control the temperature and hence resonant frequency of accelerating cavities.

A preliminary estimate of the number of channels in the linac vacuum and cooling systems is given in Table 4-1 below.

Table 4-1. Vacuum and cooling systems channel estimate for DTL

System	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
Vacuum systems				
Pumps (ion)	4	4	16	
Pumps (turbo) (+ mechanical)	2	8	16	
Vacuum valves	6	4	24	
Vacuum valves (beam-line)	2	4	16	
Pressure gauges, etc.	6	8	48	112
Cooling systems				
Independent rf cooling loops	4	12	48	
Independent magnet loops	0	1	0	48

Table 4-2. Vacuum and cooling channel estimate for CCDTL and CCL (combined)

System	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
Vacuum systems				
Pumps (ion)	160	2	320	
Pumps (turbo) (+ mechanical)	80	8	640	
Vacuum valves	80	4	320	
Vacuum valves (beam-line)	12	4	48	
Pressure gauges, etc.	104	8	832	2,160
Cooling system				
Independent rf cooling loops	56	10	560	
Independent magnet loops	10	7	70	630

4.2 POWER SUPPLY SYSTEMS

A preliminary estimate of the number of channels in the magnet power supply systems is given in Table 4-3–4-4 below.

Table 4-3. Magnet power supply system channel estimate for DTL

Magnet power supplies	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
Quadrupole power supplies	0	10	0	
Variable shunts	0	3	0	
Steering dipole power supplies	2	10	20	20

Table 4-4. Magnet power supply system channel estimate for CCDTL and CCL (combined)

Magnet power supplies	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
Quadrupole power supplies	60	10	600	
Variable shunts	386	3	1,158	
Steering dipole power supplies	30	10	300	2,058

4.3 BEAM DIAGNOSTIC SYSTEMS

A preliminary estimate of the number of channels in the linac beam instrumentation and diagnostics systems is given in Table 4-5 below.

Table 4-5. Diagnostic subsystem channel estimate for DTL

Beam diagnostics	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
dc beam current	1	5	5	
Pulsed beam current	3	5	15	
Beam position monitors	3	6	18	
Phase and energy	3	10	30	
Profile (residual gas)	6	10	60	
Beam loss (ion chamber)	5	15	75	203

Table 4-6. Diagnostic Subsystem channel estimate for CCDTL and CCL (combined)

Beam diagnostics	Number of systems	Channels per System (read/write)	Estimated Channels (read/write)	Total channels
dc beam current	2	5	10	
Pulsed beam current	12	5	60	
Beam position monitors	121	6	726	
Phase and energy	48	10	480	
Profile (flying wire)	5	10	50	
Profile (residual gas)	6	10	60	
Beam loss (ion chamber)	72	15	108	2,466

Table 4-7. Diagnostics channel estimate for relevant sections of the HEBT

Beam diagnostics	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total channels
dc beam current	1	5	5	
Pulsed beam current	5	5	25	
Beam position monitors	35	6	210	
Phase and energy	5	10	50	
Wall current	1	4	4	
Halo scrapers	4	6	24	
Bunch length (Fourier)	1	5	5	
Bunch length (Witkover)	1	5	5	
Bunch length (LINDA)	1	5	5	
Beam in gap	1	5	5	
Profile (residual gas)	6	10	60	
Beam loss (ion chamber)	33	15	495	893

Note: Other systems are included with the ring and transport.

4.4 CONTROL SYSTEMS FOR LINAC RF SYSTEMS

The rf system divides clearly into two distinct subsystems: the high power rf system (HPRF) and the low-level rf systems (LLRF).

The HPRF system includes the klystrons, power amplifiers, transmitters, recirculators, etc. which provide power to accelerating cavities. These systems are generally acquired as complete packages, including a local control system, usually using a PLC. The scope of the HPRF supervisory control system includes assuring that the local control systems provided with this equipment can be seamlessly integrated into the SNS integrated control system. The control system includes the IOCs (VME or PC-based), processors and appropriate interfaces to the local, vendor-provided control. In addition to the local (IOC) database, some high-level local analysis software as well as subsystem-specific client applications and operator displays related to these subsystems, are included in this scope.

The LLRF system is *itself* a control system – it controls the frequency of the cavities using fast feedback systems. The supervisory control system for linac low level rf system provides the interface between the LLRF *electronics* and the SNS integrated control system. It includes only the VXI IOC powered crates and processors – the LLRF WBS provides all required input-output and fast analysis modules. In addition to the local (IOC) database, some high-level local analysis software as well as subsystem-specific client applications and operator displays related to these subsystems, are included in this scope.

A preliminary estimate of the number of channels in the linac RF systems is given in Table4-8 below.

Table 4-8. RF subsystem channel estimate for 402.5 MHz System (DTL)

RF systems	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total Channels
LLRF	2	150	300	
Transmitters	2	125	250	
High Voltage Systems	1	50	50	600

Table 4-9. RF subsystem channel estimate for 805 MHz systems (CCDTL and CCL combined)

RF systems	Number of systems	Channels per system (read/write)	Estimated channels (read/write)	Total Channels
LLRF	56	150	8,400	
Transmitters	28	125	3,500	
High Voltage Systems	7	50	350	12,250

5. RING CONTROLS (1.9.5)

This WBS provides hardware and software to integrate signals from the Ring, HEBT and RTBT systems. The interface between the ICS and these systems (WBS 1.5) is at the IOC (See Figure1.2). WBS 1.5 is responsible for field equipment, signal cabling, non-VME hardware and its associated software. WBS 1.9.5 is responsible for IOC hardware, IOC software, development of subsystem-specific client applications, and related operator displays.

Devices to be controlled and corresponding I/O data for the Ring, HEBT and RTBT lines are listed in the tables below.

Power supplies consist of DC supplies and ramping supplies for the injection system. For the injection power supplies the control system must monitor a coordinated ramp during injection (1.2 millisec.). The setpoint rate is low for the DC supplies, however a fast readback rate (>60Hz) will be needed for the analysis of the cause of beam aborts.

Table 5-1. Vacuum Data

Equipment	# Items	# Channels per Item	Total Channels	Total Points Logged
		HEBT DEVICE LIST		
Sector Valves	6	3	18	6
Ion Pumps	20	5	100	20
Roughing Pumps	5	8	40	5
Gauges	5	4	20	5
Total	36		188	36
		RTBT DEVICE LIST		
Sector Valves	6	3	18	6
Ion Pumps	18	5	90	18
Roughing Pumps	5	8	40	0
Gauges	5	6	30	5
Total	34		178	29
		RING DEVICE LIST		
Sector Valves	8	3	24	8
Ion Pumps	64	5	320	64
Roughing Pumps	8	8	64	8
Gauges	16	6	96	16
Sublim. Pumps	64	4	256	64
Total	160		760	160

Table 5-2. Power Supply Data

Power Supplies	Bipolar	Resolution Bits	#Magnets	DC	#Supplies	Channels / Supply	Total Channels
				HEBT			
7.5° Dipole	No	16	1	Yes	1	25	25
7.5° Dipole	No	16	12	Yes	1	25	25
Quads	No	16	33	Yes	16	25	400
Correctors	Yes	14	37	Yes	37	15	555
Quads, linac beam dump	No	16	6	Yes	4	25	100
Total					59		1105
				RING			
Dipole	No	16	32	Yes	1	25	25
Quads, Vert.	No	16	24	Yes	1	25	25
Quads, Hor.	No	16	16	Yes	2	25	50
Octupoles	?	14	8	Yes	8	15	120
Correctors	Yes	14	96	Yes	64	15	960
Total			1				1180
				RTBT			
7.5° Dipole	No	16	1	Yes	1	25	25
Kicker Magnet	No	16	1	Yes	1	25	25
Lambertson	No	16	1	Yes	1	25	25
Quads	No	16	27	Yes	27	25	675
Quads, special	No	16	5	Yes	5	25	125
Correctors	Yes	14	33	Yes	33	15	495
Quads, extraction beam dump	Yes	15	2	Yes	2	25	50
Correctors, dump	Yes	14	2	Yes	2	15	30
Total							1450

Table 5-3. Ramping Power Supply Data

Power Supplies	#	# Signals	Resolution	Total
Ramping Supplies	8	25	13	200
Readback Waveform (100kHz digitizer)	8	120 (2sec)	14	192,000
DC Supply	2	25	14	50

6. TARGET CONTROLS (WBS 1.9.6)

Target systems requiring control services include:

- Mercury Target Assemblies
- Vessel Systems
- Shielding Systems
- Target Utility Systems
- Beam Dump Systems
- Moderator Systems
- Remote Handling Systems
- Target Protection System

Global access to target monitoring and control parameters (e.g. by operators in SNS controls rooms) will be via the EPICS system, regardless of whether implementation is via EPICS directly or via a dedicated programmable controller. WBS 1.9.6 will provide the IOCs and PLCs to control and monitor the target systems.

Remote handlingand cryogenic moderator system controls are stand-alone and separate from the ICS. However, there will be a limited interface between the two.

Normal operation of target systems will take place from the main control room. A local control room, located in the target building basement, will also be provided. This control room will be used primarily for target system start-up and shut-down and for troubleshooting.

The capability shall be provided to operate target processes from both the central control building and from a target control room located in the target building basement.

Cabling between the control system and target sensors and control elements will be provided under WBS 1.6.8.10. In general, raceways for target I&C cabling are provided under WBS 1.8.3.7.

The ICS shall interface with the Target Protection System to display system status and aid in troubleshooting.

Table 6-1 lists channel count data.

Table 6-1. Channel estimates

	IOC points[a]				PLC points				Beam Permit System
NS system	AI	AO	DI	DO	AI	AO	DI	DO	DI
Target assemblies	64	2	44	14	0	0	0	0	10
Moderator systems	0	0	2	0	0	0	0	0	2
Reflector systems	32	0	0	0	0	0	0	0	0
Vessel systems	68	0	14	0	0	0	0	0	2
Shielding systems	148	16	144	52	0	0	0	0	0
Utility systems	0	0	26	0	480	54	164	98	26
Remote handling system	10	0	30	0	0	0	0	0	0
Beam dumps	12	0	18	0	12	4	24	24	18
Grand total	334	18	278	66	492	58	188	122	58

Note: AI = analog input; AO = analog output; DI = digital input; DO = digital output.

[a]Only "hardwired" I/O points are listed. IOCs will also be required to acquire PLC, target protection system, fast protection system, and personnel protection system points via serial or network connections.

7. EXPERIMENT FACILITIES CONTROLS (WBS 1.9.7)

The primary responsibility of Experiment Facilities Controls will be to provide standard equipment and software where it is necessary. Also included in the responsibilities are the ensuring necessary links between Experiment Facilities Controls' systems and other parts of the project as well as between different subsystems of Experiment Facilities Controls. This includes the purchase of common Input/Output Controllers crates for control systems and evaluation of interface software design.

The data acquisition system for neutron scattering instruments provides a core for gathering time of flight data from the detectors. These systems are not generally off the shelf items. For this reason, responsibility for the design and procurement of these systems will be done by Experiment Facilities (WBS 1.7). These systems do require some signals that will be provided from the SNS Global Control System (WBS 1.9).

8. CONVENTIONAL FACILITIES INTERFACE (WBS 1.9.8)

The conventional facilities interface consists of hardware and software to integrate signals from conventional facilities power, HVAC, cooling water process, waste, vacuum, gases, instrument air, and other systems. The interface between the ICS and conventional facilities is at the IOC. WBS 1.8 is responsible for instruments, signal cables, PLCs and PLC programming. WBS 1.9.8 is responsible for IOCs, communications cabling to the PLC, and IOC (database) programming.

Conventional facilities signals must be integrated into the EPICS based ICS system such that only additional IOC software configuration (no hardware additions or modifications) will be needed to have supervisory control of selected parameters and all signals accessed (read, displayed, alarmed, archived, etc.) by Main Control Room operators on EPICS operator interface devices and using EPICS screens.

EPICS configuration database and graphics software will only be provided for handling 1500 key parameters (approximately three IOCs).

The ICS configuration must must be such that test, checkout, and operation of conventional facilities systems and controls within a single PLC will not require the EPICS system to be functional.

The ICS configuration must be such that test, checkout, and operation of conventional facilities systems and controls involving multiple PLC's will not be delayed by the EPICS system implementation.

The ICS configuration must allow all conventional facilities signals (including signals from embedded controllers in chillers, DI water skids, and other major components) to be displayed in a human machine interface (HMI) system in the Conventional Facilities Control Center (CFCC).

The ICS configuration must allow testing of the PLC to ICS interface via a portable EPICS system or some other appropriate arrangement.

The time delay from instrumentation sensing a parameter change to its being updated on ICS displays in the control room shall be no more than 1 second.

The ICS configuration must allow the database driving the HMI for conventional facilities to be updated from the EPICS database.

9. PERSONNEL PROTECTION SYSTEM INTERFACE (1.9.9)

The Personnel Protection System (PPS) consists of personnel entry controls to areas with radiological hazards and oxygen deficiency hazard (ODH) monitors and alarms in areas where oxygen deficiency can be a hazard. Detailed requirements for these systems are included in the Systems Requirements Document for Personnel Protection Systems, SNS 109090000-SR0001. This system does not include Lockout/Tagout (LOTO) devices for electrical power systems equipment. It also does not include a LOTO panel in the Main Control Room.

10. CENTRAL HELIUM LIQUEFIER AND CRYOMODULES INTERFACE (WBS 1.9.10)

This interface consists of hardware and software to integrate signals from the Central Helium Liquefier (CHL) and cryogenics sensors on 29 Linac cryomodules (11 channels per cryomodule).

The interface for CHL equipment is at an integrating PLC that is connected to an IOC. WBS 1.4 is responsible for instruments, signal cables, skid mounted PLCs and PLC programming. WBS 1.9.10 is responsible for the integrating PLC, IOCs, communications cabling to the IOC and (database) programming. The interface for cryomodules is at connectors on sensor feedthroughs. WBS 1.4 is responsible for the sensor and feedthrough. WBS 1.9.10 is responsible forthe integrating PLC, IOCs, communications cabling to the IOC, (database) programming, and cabling from the PLC/IOC to a junction box or feedthrough connector.

All signals must be integrated into the EPICS based ICS system such that only additional IOC software configuration (no hardware additions or modifications) will be needed to have supervisory control of selected parameters and all signals accessed (read, displayed, alarmed, archived, etc.) by Main Control Room operators on EPICS operator interface devices and using EPICS screens.

EPICS configuration database and graphics software will be provided for handling all parameters.

The ICS configuration must be such that test, checkout, and operation of these systems and controls will not require the EPICS system to be functional.

The ICS configuration must allow testing of the PLC to ICS interface via a portable EPICS system or some other appropriate arrangement.

The time delay from instrumentation sensing a parameter change to its being updated on ICS displays in the control room shall be no more than 1 second.